

**REPRODUCTIVE BEHAVIOR OF *COPITARSIA CONSUETA*
(WALKER) (LEPIDOPTERA: NOCTUIDAE):
MATING FREQUENCY, EFFECT OF AGE ON MATING,
AND INFLUENCE OF DELAYED MATING ON
FECUNDITY AND EGG FERTILITY**

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Abstract. — This study determined: mating frequency, effect of age on mating, and effect of delayed mating on fecundity and egg fertility of *Copitarsia consueta* (Walker). Females copulated (mean \pm SD) 2.5 ± 1.2 times (range 1–6), but only once per night. Mating frequency increased with moth age. Males mated an average of 2.4 ± 1.5 times during their lives (range 1–7), although only once per night. *Copitarsia consueta* start mating two days after emergence, although only 33% of the pairs mated this early. Mating frequency increased with moth age, reaching a peak 7 days after eclosion. Females mated when 2 days old laid significantly more eggs than those in which mating was delayed till 4, 6, and 8 days after eclosion. Fertility was 70.2% in females mating when 2 days old. It decreased to 50.9, 6.5, and 0.4% when mating was delayed until 4, 6, and 8 days after eclosion, respectively.

Key Words. — Insecta, *Copitarsia consueta*, mating, fecundity, fertility

The moth, *Copitarsia consueta* (Walker), is a polyphagous pest found in Mexico and Central and South America (Angulo & Weigert 1975, Gutierrez & MacGregor 1983) where it is a important pest of cultivated plants. In some regions of Mexico it is a key pest of cabbage, but it also attacks many other plants (Gutierrez & MacGregor 1983, Guevara & Cervantes 1991). The quality and quantity of cabbage are greatly affected by *C. consueta* as only one larvae is sufficient to destroy the plant (Monge et al. 1984). Information on biology of *C. consueta* is scarce (Artigas & Angulo 1973), and its reproductive behavior is unknown.

This study determined: mating frequency, effect of age on mating, and effect of delayed mating on fecundity and egg fertility of *C. consueta*.

MATERIALS AND METHODS

Insects. — Moths used in this study were reared on an artificial diet (Cibrián-Tovar & Sugimoto 1992) at $25 \pm 2^\circ$ C and $65 \pm 5\%$ RH. Male and female pupae were held separately in growth chambers under 14:10 (L:D) photoperiod. The night after emergence, the insects were placed in glass cages (20 \times 20 cm) with 10% sugar solution dispensed from shell vials plugged with cotton, and maintained at the conditions described above.

Female Mating Frequency. — Newly emerged females and an equal, or greater, number of males were confined in a glass cage (20 \times 20 cm) and provided a solution of 10% sugar in water. After dying, 100 females were dissected and the

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number of spermatophores in the bursa copulatrix counted to determine the number of times the female had mated. To determine the effect of age on mating frequency, groups of females ($n = 15$) were placed with 3–5 d old males in plastic containers ($4 \times 4 \times 7$ cm). Females were held for 2 to 7 d before being removed from the cage, killed and dissected to determine the number of spermatophores in the bursa copulatrix.

The maximum number of matings per night was determined by holding a female (2–3 d old) in a plastic container with 2 to 3 virgin males for one night. The female was killed, dissected, and the number of spermatophores counted. The experiment was repeated 20 times.

Male Mating Frequency.—A 1 d old virgin male and a 2–3 d old female were placed in a plastic container. Every 2 d the female was replaced with another 2–3 d old until the male died. The experiment was repeated 15 times. The females were dissected and the number of spermatophores present was counted.

The number of times a male could copulate per night was determined by placing a 2–3 d old male with 2 or 3 virgin females. Females were killed the next day, dissected and the number of spermatophores counted. The experiment was repeated 20 times.

Effect of Age on Mating.—Virgin males and females were placed individually in plastic containers. The experiments were conducted using insects of the following age groups: 1) male and female of equal age, ranging from 1 to 7 d old; 2) 1 d old female with a 3–5 d old male; and 3) 1 d old male with a 3–5 d old female. After each scotophase 15 females were killed, dissected, and the number of spermatophores counted.

Effect of Delayed Mating on Fecundity and Egg Fertility.—Five treatments were run: 1) 2 d old females with 3–5 d old males; 2) 4 d old females with 3–5 d old males; 3) 6 d old females with 3–5 d old males; 4) 8 d old females with 3–5 d old males; and 5) unmated females. When the male died it was replaced with another 3–5 d old male. All treatments were repeated 14 times. For each group, preoviposition period (days), oviposition period (days), fecundity (eggs/female), and fertility (%) were recorded. Dead females were dissected and the number of spermatophores determined.

Statistical Analysis.—The data were analyzed by ANOVA and the Student-Neumann-Kuels test. The preoviposition, oviposition, and fecundity data were square-root transformed and fertility data were square root arcsine transformed before analysis. The percentage of mating were analyzed using the X^2 test. Untransformed data are presented.

RESULTS AND DISCUSSION

Female Mating Frequency.—Females had an average of (mean \pm SD) 2.5 ± 1.2 spermatophores (range 1–6). Twenty-three females had 1 spermatophore, 28 had 2 spermatophores, 25 females had 3 spermatophores, 17 females had 4 spermatophores, 5 females had 5 spermatophores, and only 2 females received 6 spermatophores.

Similar results were observed in *Pseudoplusia includens* (Walker), with an average of 2.2 ± 0.2 spermatophores per female (ranging 0–5) (Mason & Johnson 1987). By comparison, females of *Chilo partellus* (Swinhoe) copulated only once (Unnithan & Paye 1991). There are two mating systems in Lepidoptera, those

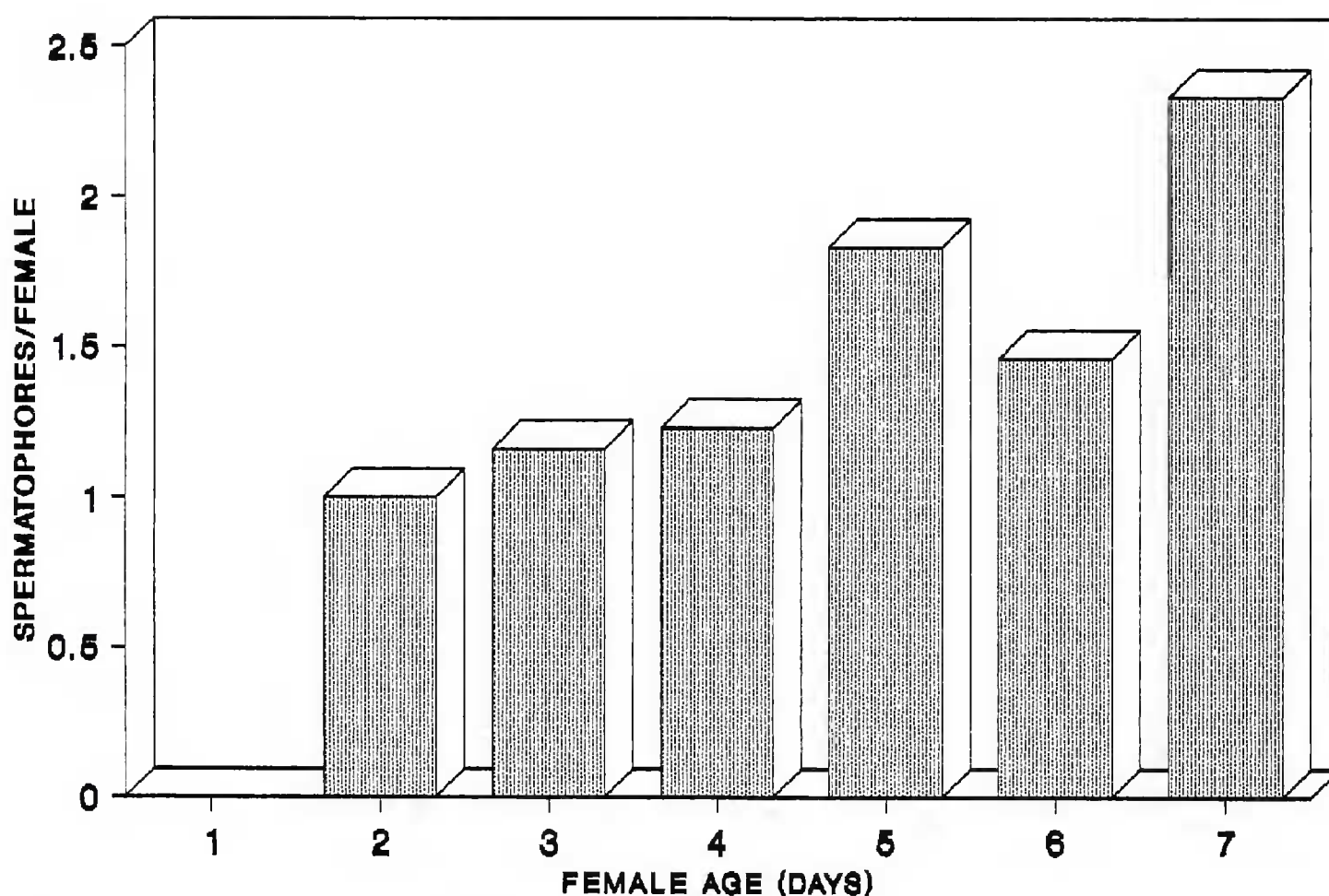


Figure 1. Mating frequency in *C. consueta* females with respect to age.

that copulate only once, and those that have multiple matings. The benefits of multiple matings differ among species. Watanabe (1988) showed that multiple matings increased the fecundity of *Papilio xuthus* L., but fertility was not increased in *Orgyia pseudotsugata* (McDonaough) despite females copulating several times (Swaby et al. 1987). The most probable benefits of multiple matings are to remedy an inadequate initial copula, to enhance genetic diversity, and to facilitate a paternal nutritional investment (Byers 1978). Traditionally, the role of multiple matings in Lepidoptera has been discussed in terms of sexual selection (Thornhill & Alcock 1983).

The *C. consueta* females only mated once per night, although they copulated repeatedly during their lives. *Spodoptera littoralis* (Boisduval) females (84%) mated only once per night, but the rest (16%) mated twice a night (Kehat & Gordon 1975).

Older females mated more frequently (Fig. 1). Landolt & Curtis (1991) had similar results with field and laboratory populations of *Amyelois transitella* (Walker).

We do not know if the mating frequency of *C. consueta* in the wild is equal or different from that observed in the laboratory. It could argue that the mating frequency in the field is less because under natural conditions the insects are distributed over a great area. *Euxoa ochrogaster* (Guenée), *Euxoa declarata* (Walker) and *Euxoa messoria* (Harris) had similar mating frequencies in field and laboratory populations (Byers 1978). Long-term laboratory strains of *Heliothis virescens* (F.) and *Pectinophora gossypiella* (Saunders) have a higher mating frequency than recently colonized strains (Proshold & Bartell 1972, LaChance et al. 1975). This study used recently colonized insects (F^1), therefore, it is likely that

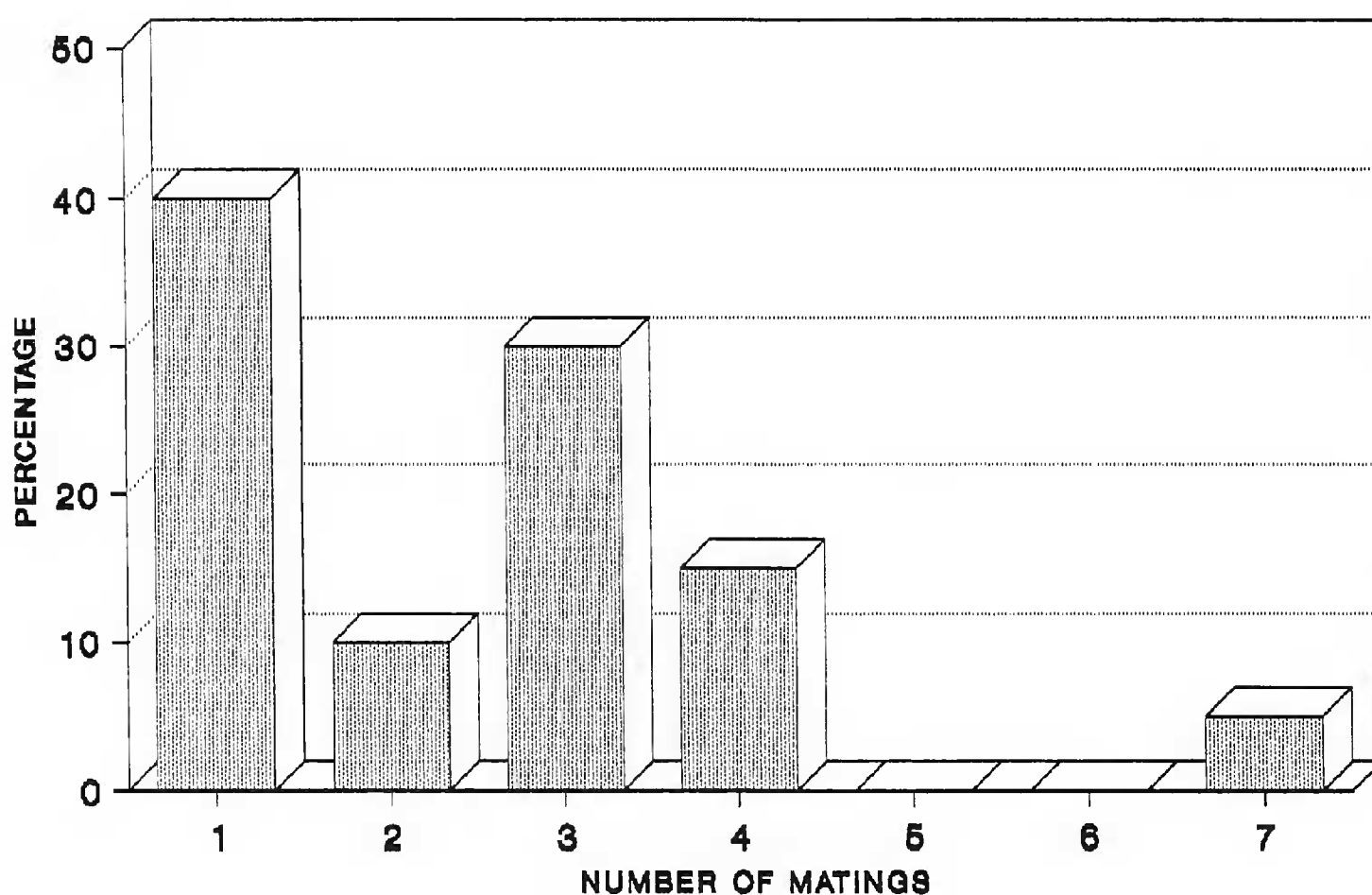


Figure 2. Mating frequency in *C. consueta* males.

mating frequency observed in the laboratory will be similar to that under natural conditions, as suggested for *Euxoa* spp. (Byers 1978).

Male Mating Frequency.—Males copulated an average of 2.4 ± 1.5 times during their life span (range 1–7) (Fig. 2). Similar trends were observed in other noctuid moths: *S. littoralis* males mated an average of 5–6 times (Kehat & Gordon 1975), *Spodoptera frugiperda* (J. E. Smith) males mated an average of 6.7 times (range 0–15) (Simmons & Marti 1992), and *C. partellus* males mated a mean of 4.6 ± 0.4 times (Unnithan & Paye 1991).

The males of *C. consueta* mated only once per night. Similar results were reported for *S. littoralis* (Kehat & Gordon 1975) and *Spodoptera exempta* (Walker) (Khasimuddin 1978), whereas, in *C. partellus*, 90% mated once and 6% mated twice (Unnithan & Paye 1991).

Effect of Age on Mating.—*Copitarsia consueta* start mating two days after emergence, although only 33% of the pairs mated this day (Fig. 3). Mating frequency increased with the age reaching a peak 7 d after eclosion in this experiment. The differences in the percentage of mating pairs for 4, 5, 6 and 7 d are not significant ($X^2 = 1.18$; $df = 3$, $P > 0.05$). The age of the female is important if mating is to be successful, as the pairs that had 1 d old females failed to mate. The pairs with 3–4 d old females mated 12.4% of the time. These results mirror the calling behavior of the females. No female called the day following emergence. Females called for the first time during the second or third scotophase after eclosion (JCR, unpublished data).

Moths can be placed in two groups according to age at which mating, those that mate soon after eclosion, such as *C. partellus* (Unnithan & Paye 1991) and *Spodoptera ornithogalli* (Guenée) (Shorey et al. 1968); and those that need time

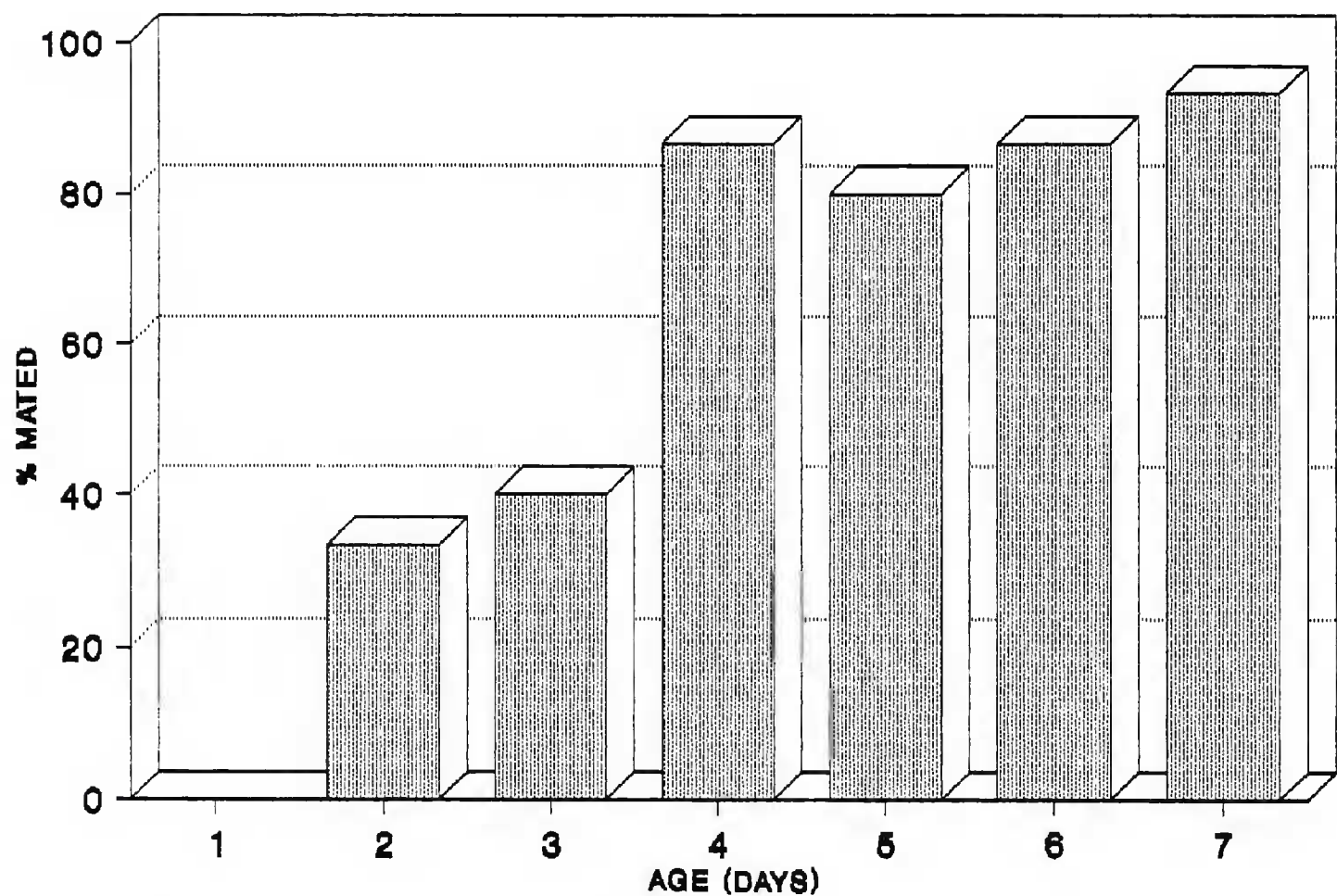


Figure 3. Effect of age on the mating capacity of *C. consueta*.

to reach sexual maturity like *C. consueta*. This group includes *S. exempta* (Khasimuddin 1978) and *Corcyra cephalonica* (Stainton) (Etman et al. 1988).

That only a few 1 d old males copulated with mature females could be due to: 1) that they are not sexually mature and thus do not respond to sex pheromone; as occurs in *S. exempta* (Khasimuddin 1978) and 2) that males are rejected because they do not provide the proper stimulus for mating, as has been suggested for *Anticarsia gemmatilis* (Hubner) males (Leppla et al. 1987). We do not know which mechanism occurs in *C. consueta*; this will be investigated in the future.

Effect of Delayed Mating and Fecundity and Egg Fertility.—The percentages of females mating after 2, 4, 6, and 8 d did not differ significantly ($X^2 = 1.6$; $df = 3$; $P > 0.05$). These results differ from those reported for *Homona magnanima* Diakonoff and *P. gossypiella*, in which the percentage of mated females decreased with an increase in the number of days elapsing before pairing (Kiritani & Kanoh 1984, Lingren et al. 1988).

The preoviposition period increased significantly with delayed mating ($F = 7.3$; $df = 3, 52$; $P < 0.05$) (Table 1). Similar results were reported in *C. partellus* (Unnithan & Paye 1991).

The ovipositional period differed significantly among treatments ($F = 3.6$; $df = 3, 52$; $P < 0.05$). The same phenomenon was reported for *H. magnanima*, *P. gossypiella*, and *C. partellus* (Kiritani & Kanoh 1984, Lingren et al. 1988, Unnithan & Paye 1991).

Females mating at 2 d old laid significantly more eggs than those in which mating was delayed till 4, 6, and 8 d ($F = 17.7$; $df = 3, 52$; $P < 0.05$). The effect of delayed mating on eggs fertility was significant ($F = 36.7$; $df = 3, 52$; $P < 0.05$). Fertility was 70.2% in females mating at 2 d old, and it decreased with age. The

Table 1. Influence of delayed mating on reproductive biology of *C. consueta*.

Age at mating (days)	% of mating	Preoviposition period (days) ($\bar{x} \pm SE$)	Oviposition period (days) ($\bar{x} \pm SE$)	Fecundity (eggs/female) ($\bar{x} \pm SE$)	Fertility (%) ($\bar{x} \pm SE$)
2	86.6	5.0 \pm 0.5 ^a	12.4 \pm 1.3 ^a	1638.8 \pm 199.7 ^a	70.2 \pm 8.6 ^a
4	83.3	5.4 \pm 0.4 ^a	7.0 \pm 1.6 ^b	976.8 \pm 248.1 ^b	50.9 \pm 11.6 ^b
6	78.5	6.3 \pm 0.4 ^a	8.4 \pm 1.5 ^b	283.5 \pm 84.9 ^c	6.5 \pm 6.4 ^c
8	78.5	10.6 \pm 0.8 ^b	7.0 \pm 1.3 ^b	220.0 \pm 67.8 ^d	0.4 \pm 0.2 ^d
Unmated females	—	(14.2 \pm 3.3) ^a	(2.3 \pm 0.7) ^a	(131.5 \pm 56.9) ^a	—

Means within columns followed by the same letters are not significantly different (Student-Newman-Keuls test, $P < 0.05$).

^a Data are not included in analysis.

effect of delaying mating on fecundity and fertility in Lepidoptera is variable. Barrer (1976) found in *Ephestia cautella* (Walker) that when mating was delayed, the fecundity and fertility were reduced. Similar results were reported in *S. littoralis*, *H. magnanima*, *P. gossypiella*, and *C. partellus* (Ellis & Steele 1982, Kiritani & Kanoh 1984, Lingren et al. 1988, Unnithan & Paye 1991). However, in *Erias insulana* (Boisduval) (Kehat & Gordon 1977) and the Israeli strain of *S. littoralis* (Kehat & Gordon 1975) delays in mating do not have an effect on fecundity and fertility. Reduced fecundity of *C. consueta* females that experience a delay in mating could be due to the resorbing of eggs as has been suggested for *E. cautella* (Barrer 1976).

The use of sex pheromones to delay mating, and hence provide control of *C. consueta*, requires a delay of 8 d between adult emergence and mating to prevent the laying of viable eggs. Delays of less than 8 d would lead to the production of progeny. Delaying of mating has been proposed as the principal mechanism leading to successful mating disruption against *P. gossypiella* (Lingren et al. 1988).

ACKNOWLEDGMENT

JCR thanks CONACyT for a graduate fellowship (register No 62158). This research was supported by a CONACyT grant (0691-N9111).

LITERATURE CITED

Angulo, O. A. & G. Th. Weigert. 1975. Estados inmaduros de Lepidópteros noctuidos de importancia económica en Chile y claves para su determinación (Lepidoptera: Noctuidae). Soc. Biol. Concepción, publicación especial 2.

Artigas, J. N. & A. O. Angulo. 1973. *Copitarsia consueta* (Walker), biología e importancia económica en el cultivo de raps (Lepidoptera: Noctuidae). Bol. Soc. Biol. Concepción, 46: 199–216.

Barrer, P. M. 1976. The influence of delayed mating on the reproduction of *Ephestia cautella* (Walker) (Lepidoptera: Noctuidae). J. Stored Prod. Res., 12: 165–169.

Byers, J. R. 1978. Biosystematics of the genus *Euxoa* (Lepidoptera: Noctuidae). X. Incidence and level of multiple mating in natural and laboratory populations. Can. Ent., 110: 193–200.

Cibrián-Tovar, J. & A. Sugimoto. 1992. Elaboración de una dieta artificial para la cría de *Copitarsia consueta* (Walker) (Lepidoptera: Noctuidae). pp. 416. In Memorias del XXVII Congreso Nacional de Entomología. Sociedad Mexicana de Entomología.

Ellis, P. E. & G. Steele. 1982. Effects of delayed mating on fecundity of females of *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae). Bull. Entomol. Res., 72: 295–302.

Etman, A. A. M., F. M. A. El-Sayed, N. M. Eesa & L. E. Moursy. 1988. Laboratory studies on the

- development, survival, mating behavior and reproductive capacity of the rice moth, *Corcyra cephalonica* (Stainton). J. Appl. Ent., 106: 232–240.
- Guevara, A. R. & J. F. Cervantes. 1991. Insectos plaga de hortalizas en la zona chinampera de Xochimilco, D. F. pp. 528–529. In *Memorias del XXVI Congreso Nacional de Entomología*. Sociedad Mexicana de Entomología.
- Gutierrez, O. & R. MacGregor. 1983. Guía de insectos nocivos para la agricultura en México. Alhambra Mexicana, México, D.F.
- Kehat, M. & D. Gordon. 1975. Mating, longevity, fertility and fecundity of the cotton leaf-worm, *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae). *Phytoparasitica*, 3: 87–102.
- Kehat, M. & D. Gordon. 1977. Mating ability, longevity and fecundity of the spiny bollworm, *Earias insulana* (Lepidoptera: Noctuidae). *Entomol. Exp. Appl.*, 22: 267–273.
- Khasimuddin, S. 1978. Courtship and mating behavior of the African armyworm, *Spodoptera exempta* (Walker) (Lepidoptera: Noctuidae). *Bull. Entomol. Res.*, 68: 195–202.
- Kiritani, K. & M. Kanoh. 1984. Influence of delayed mating on the reproduction of the oriental tea tortrix, *Homona magnanima* Diakonoff (Lepidoptera: Tortricidae), with reference to pheromone-based control. *Prot. Ecol.*, 6: 137–144.
- LaChance, L. E., R. D. Richard & F. I. Proshold. 1975. Radiation response in the pink bollworm: a comparative study of sperm bundle production, sperm transfer, and oviposition response elicited by native and laboratory-reared males. *Environ. Entomol.*, 4: 321–324.
- Landolt, P. J. & C. E. Curtis. 1991. Mating frequency of female navel orangeworm moths (Lepidoptera: Pyralidae) and patterns of oviposition with and without mating. *J. Kansas Entomol. Soc.*, 64: 414–420.
- Leppa, N. C., R. H. Guy, R. R. Heath & B. Dueben. 1987. Laboratory studies of the courtship of the velvetbean caterpillar moth, *Anticarsia gemmatilis* (Hubner) (Lepidoptera: Noctuidae). *Ann. Entomol. Soc. Am.*, 80: 278–283.
- Lingren, P. D., W. B. Warner & T. J. Henneberry. 1988. Influence of delayed mating, on egg production, egg viability, mating, and longevity of female pink bollworm (Lepidoptera: Gelechiidae). *Environ. Entomol.*, 17: 86–89.
- Mason, L. J. & S. J. Johnson. 1987. Observations on the mating behavior of *Pseudoplusia includens* (Lepidoptera: Noctuidae). *Fla. Entomol.*, 70: 411–413.
- Monge, V. L., J. G. Vera, S. I. Gil & J. L. Carrillo. 1984. Efecto de las practicas culturales sobre las poblaciones de insectos y daño causado al cultivo del repollo (*Brassica oleraceae* var. *capitata*). *Agrociencia*, 57: 109–126.
- Proshold, F. I. & J. A. Bartell. 1972. Difference in radiosensitivity of two colonies of tobacco budworm, *Heliothis virescens* (Lepidoptera: Noctuidae). *Can. Ent.*, 104: 995–1002.
- Shorey, H. H., S. U. McFarland & L. K. Gaston. 1968. Sex pheromone of noctuid moths. XIII. Changes in pheromone quantity, as related to reproductive age and mating history, in females of seven species of Noctuidae (Lepidoptera). *Ann. Entomol. Soc. Am.*, 61: 372–376.
- Simmons, A. M. & O. G. Marti Jr. 1992. Mating by the fall armyworm (Lepidoptera: Noctuidae): frequency, duration, and effect of temperature. *Environ. Entomol.*, 21: 371–375.
- Swaby, J. A., G. E. Daterman & L. L. Sower. 1987. Mating behavior of douglas-fir tussock moth, *Orgyia pseudotsugata* (Lepidoptera: Lymantriidae), with special reference to effects of female age. *Ann. Entomol. Soc. Am.*, 80: 47–50.
- Thornhill, R. & J. Alcock. 1983. The evolution of insects mating systems. Harvard University Press, Cambridge.
- Unnithan, G. C. & S. O. Paye. 1991. Mating, longevity, fecundity, and egg fertility of *Chilo partellus* (Lepidoptera: Pyralidae): effects of delayed or successive matings and their relevance to pheromonal methods. *Environ. Entomol.*, 20: 150–155.
- Watanabe, M. 1988. Multiple mating increase the fecundity of the yellow swallowtail butterfly, *Papilio xuthus* L., in summer generations. *J. Insect. Behav.*, 1: 17–29.